Observations on Some Pleistocene Outcrops in Cambodia

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Observations on some Pleistocene outcrops in Cambodia

by

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I Introduction

The present paper is based upon a brief field trip made by the writer from May 26 through June 1, 1967, subsequent to his ten month geological survey in central Thailand.

One of the main objectives of this trip was to examine and compare the probable stratigraphical correlations of the Quaternary deposits in Cambodia with those of Thailand. The writer has elsewhere[1] proposed a provisional scheme for the Quaternary stratigraphy of Thailand. For this purpose the survey was done with special attention to the characteristic weathering pattern that developed on the formations of each of the Quaternary geological bodies.

The project was part of the research program of the Center for Southeast Asian Studies of Kyoto University.

II Descriptions of outcrops

Eight areas, as shown in Fig. 1, were selected to show the outlines of the geological mode of young sediments. They are described in the following:

1. Kompong Chhnang area

Geological mode of this area is as shown in Fig. 2.

1-i) 26 km NW of Kompong Chhnang along National Road No. 5

Ground surface: Undulating with thorny bushes and small patches of paddy.

0.0-0.3m: Thin lateritic pan with common pink quartz grains (ϕ 1-3 mm). Gradual and uneven boundary to;

0.3-1.0m: Heavily weathered clayey sand; hard when dry; friable when moist; yellowish to brownish gray color with large reddish brown mottlings.

Numerous pink quartz grains are scattered throughout the sediments.

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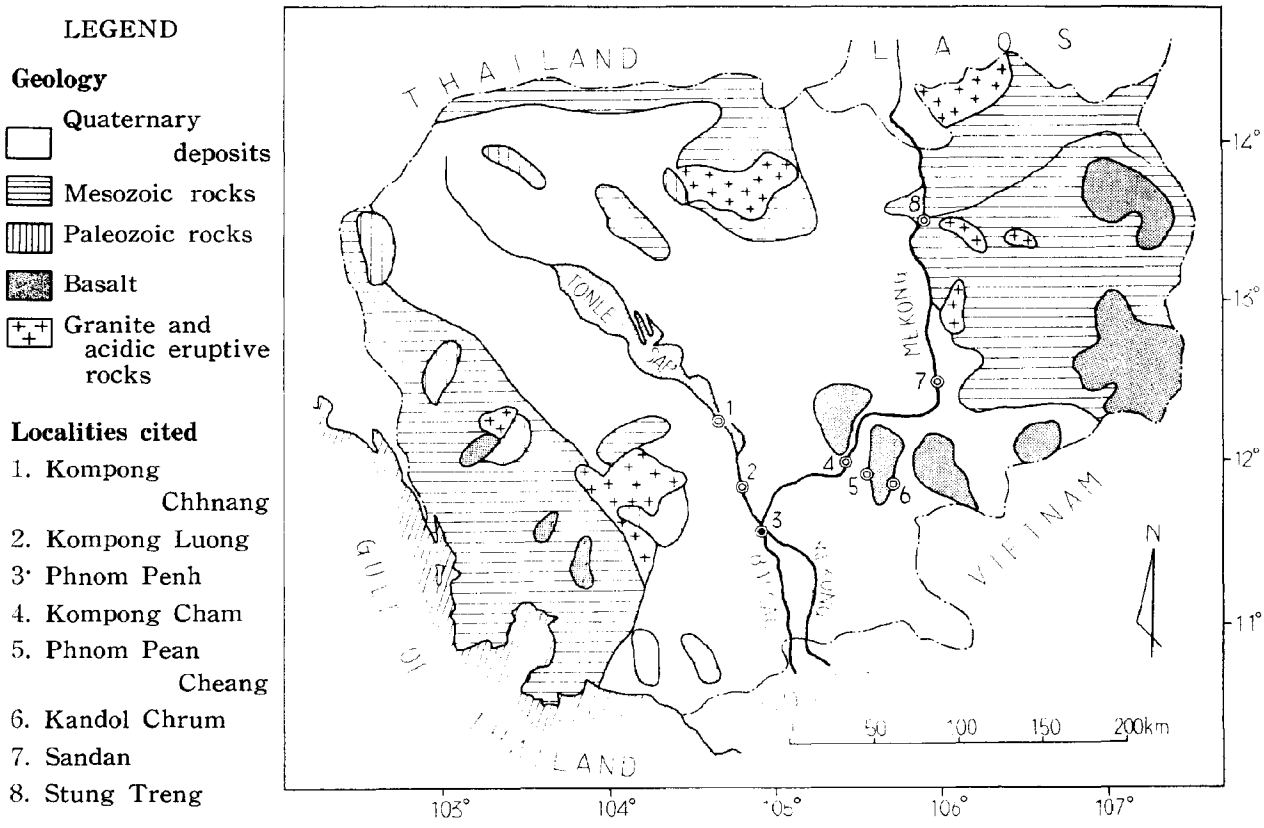


Fig. 1 Index map of Cambodia (after Cambodge Geologique 1/2,500,000)

1-ii) 21 km NW of Kompong Chhnang along National Road No. 5

Ground surface: Rolling hill composed of quartzite with the surface covered by dwarf trees and bushes.

No alluvium is found on the hill top and almost pure quartz sand, which is apparently the residue of the underlying quartzite, develops spaciously.

1-iii) 16 km NW of Kompong Chhnang along National Road No. 5

Ground surface: Undulating, with thorny bushes and small patches of paddy fields.

0.0-0.3m: Heavily weathered sand; light gray when dry; yellowish gray when moist and wet ; without any visible weatherable primary minerals. Abrupt and smooth boundary to;

0.3-0.6m: Reddish brown loose laterite.

0.6-1.6m: Heavily weathered silty or clayey sand, with pink quartz grains.

General features are quite similar to those of Loc. 1-i.

1-iv) 5 km NW of Kompong Chhnang along National Road No. 5

Ground surface: Undulating surface circling a small hill composed of volcanic rocks.

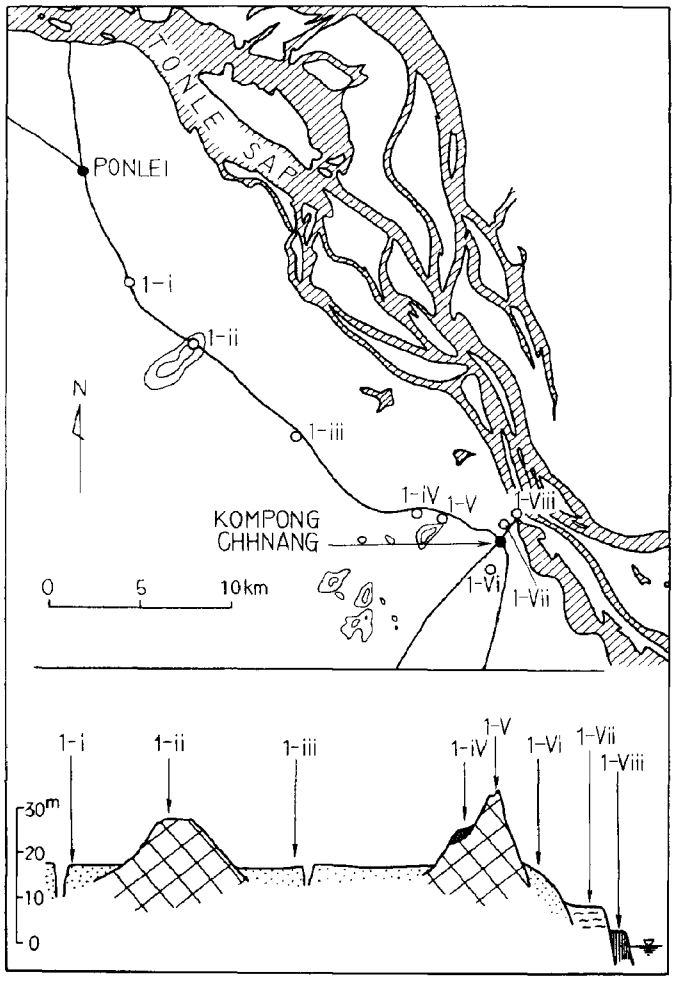


Fig. 2 Geological mode of Kompong Chhnang area

0.0-1.2m : Hard laterite ; vesiculately textured. The lithofacies are quite similar to those of the thick ferruginous crust developed on the peneplains in Thailand. Lower limit is unknown.

1-v) 4 km NW of Kompong Chhnang along National Road No. 5

Small mountain of volcanic rock with steep side slopes.

1-vi) 1 km SW of Kompong Chhnang

Ground surface : Undulating, covered with bushes and grasses and small rice fields.

0.0-0.05m : Laterite layer with many quartz grains (ϕ 2-4 mm).

0.05-1.0m : Fine to medium sand with abundant pink quartz grains (ϕ 2-4 mm) ; light gray when dry and yellowish gray when wet. No weatherable primary minerals are found.

1-vii) 1.8 km NE of Kompong Chhnang

Ground surface : High flood plain covered with paddy. Surface is about

10 m above the water level of the Tonle Sap (May 30).

1-viii) 2 km NE of Kompong Chhnang

Ground surface: Narrow flood plain with a small back swamp. Surface is about 4 m higher than the water level of the Tonle Sap (May 30).

2. Kompong Luong area

Geological mode of this area is as shown in Fig. 3.

2-i) Kompong Luong Ferry, on the right bank of the Tonle Sap

Ground surface: Slightly undulating; 7.4 m above the water level of the Tonle Sap (May 27).

0.0-4.6m: Loam or sandy loam; massive; weakly stratified in part; dark brown and loose when moist; with iron oxide concentrations sparsely scattered. Abrupt boundary to;

4.6-5.8m: Light yellowish gray clay mottled with bluish gray color when moist. Calcareous concretions (1.5cm in long dimension) and pisolitic concretions (ϕ 3-8 mm) of iron oxide in rare occurrences.

5.8-7.4m: Clay; bluish gray to slightly yellowish gray when moist; without concretions.

2-ii) Swampy area just behind the flood plain

Ground surface: About 8 m above the water level.

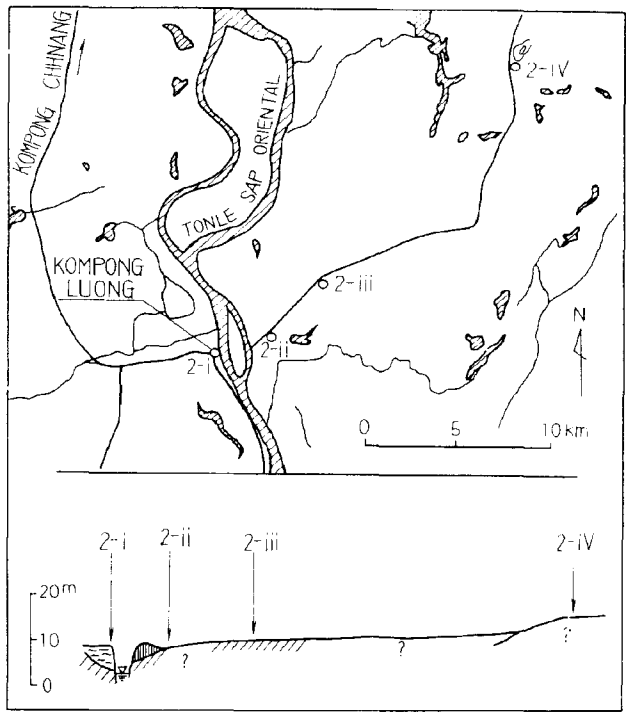


Fig. 3 Geological mode of Kompong Luong area

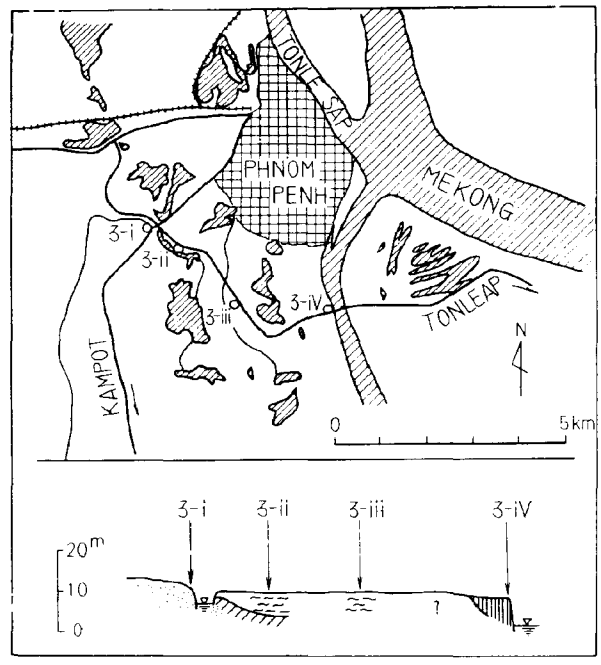


Fig. 4 Geological mode of Phnom Penh area

2-iii) 7 km NW of Kompong Luong Ferry along National Road No. 6

Ground surface : Slightly undulating paddy field with standing trees. Surface is about 12 m above sea level.

0.0-1.0m : Yellowish gray clay with pisolitic concretions (ϕ 3-8 mm) of iron oxide.

2-iv) 20 km NE of Kompong Luong Ferry along National Road No. 6

Ground surface : A few meter higher than at Loc. 2-iii.

3. Phnom Penh area

Geological mode is as shown in Fig. 4.

3-i) Samdach Monireth bridge, on the right bank of the Steng Mean Chey

Ground surface : Undulating open land; 5 m above the water level of the Steng Mean Chey and about 13 m above sea level.

0.0-1.0m : Very heavily weathered fine sand and silt ; mottled in yellowish gray and reddish yellow when wet ; with common pisolitic concretions (ϕ 3-8 mm) of iron oxide.

1.0-1.2m : Aggregate of pisolitic and botryoidal concretions of iron oxide. Transforms to a loose lateritic pan in cases.

1.2-4.5m : Very heavily weathered silt and fine sand ; grayish yellow color with reddish brown vesicular mottlings. Most feldspar grains appear to have been changed to kaolinic minerals.

3-ii) Samdach Monireth bridge, on the left bank of the Steng Mean Chey

Ground surface : Flat residential area of Phnom Penh city; about 11 m above sea level.

0.0-4.0m : Dark brownish massive loam. Sharp and smooth boundary to ;

4.0-4.8m : Slightly weathered yellowish gray clay with pisolitic concretions (ϕ 3-8 mm) of iron oxide.

The combination of the upper loam and the lower clay with concretions is quite similar to that at Loc. 2-i.

3-iii) Just south of Hospital de L'amitie Khmero-Sovietique

Ground surface : Slightly undulating land crop fields with numerous abandoned river courses and ponds. About 11 m above sea level.

0.0-4.0m : Dark brown massive loam without concretions.

3-iv) Monivong bridge, on the right bank of the Tonle Bassac

Ground surface : About 9 m above the water level of the Tonle Bassac (May 31).

0.0-7.5m : Dark gray sandy clay ; brownish gray in part ; weakly stratified ; with iron oxide concentrations in the upper part. Smooth boundary to ;

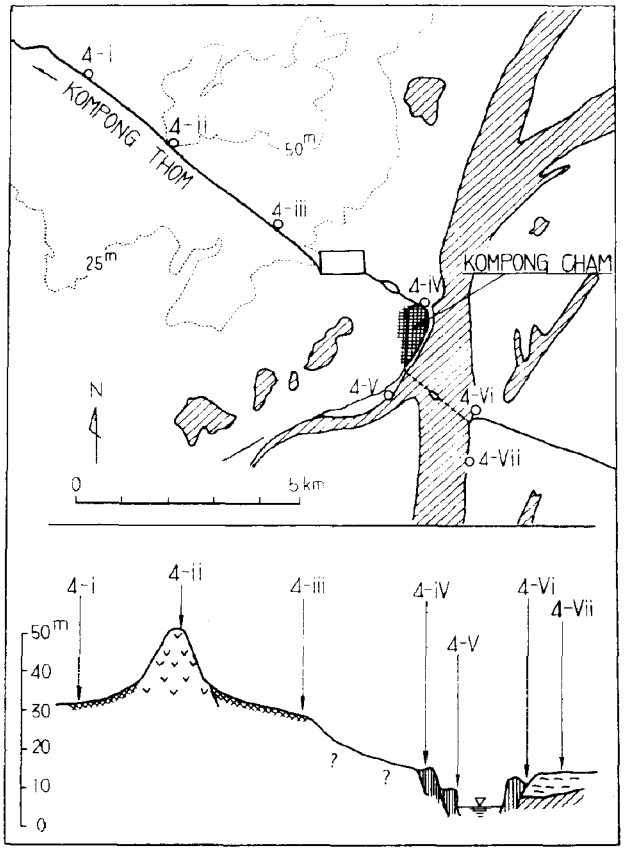


Fig. 5 Geological mode of Kompong Cham area

7.5-9.0m : Cross-bedded alternate layers of sandy clay and gravels with wood fragments. Gravels are dominantly composed of subrounded pebbles (ϕ 1-3 cm). Clay is dark gray and contains many plant fragments.

4. Kompong Cham area

Geological mode is as shown in Fig. 5.

4-i) 9 km NW of Kompong Cham Ferry along National Road No. 7

Ground surface : Undulating or slightly undulating surface covered with dwarf trees. About 40 m above sea level.

0.0-0.1m : Accumulation of pisolitic and botryoidal iron oxide concretions. Sharp boundary to ;

0.1-0.3m : Hard lateritic pan. Sharp boundary to ;

0.3-1.0m : Heavily weathered basalt.

4-ii) 7 km NW of Kompong Cham Ferry along National Road No. 7

Ground surface : Rolling hills with mixed forest. About 50 m above sea level.

0.0-0.2m : Reddish brown clayey loam ; massive ; with basalt boulder (ϕ up to 2 m).

4-iii) 4 km NW of Kompong Cham Ferry along National Road No. 7

Ground surface: Undulating or slightly undulating surface with bushes, dwarf trees and small patches of paddy. About 40 m above sea level. Numerous pisolitic and botryoidal iron oxide concretions are on the ground surface. General features are quite similar to those of Loc. 4-i.

4-iv) Kompong Cham Ferry, on the right bank of the Mekong

Ground surface: Slightly undulating surface, about 10 m above the water level of the Mekong (May 27). City of Kompong Cham is on this surface.

0.0-9.0m: Cross-bedded alternate layers of silt, fine sand and medium sand, with many plant remains and hydromica fragments.

4-v) 2 km S of Kompong Cham, on the right bank of the Mekong

Ground surface: Typical low flood plain with a surface of about 4 m above the water level of the Mekong (May 27).

0.0-4.0m: Fine to medium sand; loose.

4-vi) Kompong Cham Ferry, on the left bank of the Mekong

Ground surface: Flood plain with a narrow natural levee and back swamps. Surface of the natural levee is about 10 m above the water level of the Mekong (May 27).

0.0-5.0m: Alternate layers of dark gray silty sand and sandy silt; slightly cross-bedded.

4-vii) 200 m down stream of Kompong Cham Ferry, on the left bank of the Mekong

Ground surface: About 12 m above the water level of the river (May 27).

0.0-5.0m: Massive dark brownish gray loam; with small iron oxide concentrations.

5.0-6.0m: Gray silty clay mottled with yellowish gray; slightly weathered; pisolitic iron oxide concretions (ϕ 3-7mm) in rare occurrences.

5. Phnom Pean Cheang area

Geological mode is as shown in Fig. 6.

5-i) 13 km S of the junction with National Road No. 22, along National Road No. 15

Ground surface: Undulating to rolling surface with rubber plantations. About 50 m above sea level.

0.0-1.5m: Reddish brown clayey loam with many small (1.5 cm in long dimension) brown flakes and breccia, with rare big (ϕ 1.5 m) black boulders. Brown breccia are heavily weathered basalt fragments and big boulders are of fresh basalt. Gradual boundary to;

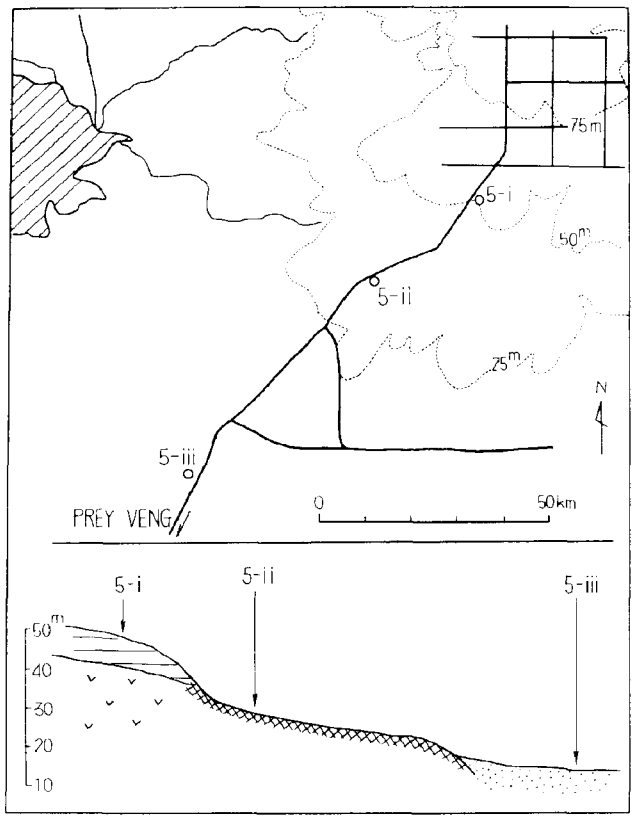


Fig. 6 Geological mode of Phnom Pean Cheang area

1.5-3.0m : Very heavily weathered basalt. Some parts appear like loose laterite.

5-ii) 16 km S of the junction with National Road No. 22, along the National Road No. 15

Ground surface : Undulating or slightly undulating surface with dwarf trees and bushes. Transitional zone between Locs. 5-i and 5-iii. About 20 m above sea level.

0.0-0.1m : Aggregate of pisolitic and botryoidal iron oxide concretions. Sharp boundary to ;

0.1-0.2m : Hard laterite.

General features of this formation are quite similar to those at Loc. 1-iv.

5-iii) 22 km S of the junction with National Road No. 22, along National Road No. 15

Ground surface : Slightly undulating paddy field with a few termite mounds. About 15 m above sea level.

0.0-0.3m : Heavily weathered fine sand ; yellowish gray color mottled with brownish gray ; with perfectly decomposed feldspars, and pink quartz grains.

0.3-0.4m: Aggregate of pisolitic and botryoidal iron oxide concretions; loose lateritic pan in part.

0.4-0.6m: Very heavily weathered fine sand with pink quartz grains.

General geological mode is quite similar to that of Loc. 1-iii.

6. Kandol Chrum area

Geological mode is as shown in Fig. 7.

6-i) 6 km SE of Suong along National Road No. 22

Ground surface: Low hill composed of basaltic rocks, capped with red soil. About 23 m above sea level.

6-ii) 9 km SE of Suong along National Road No. 22

Ground surface: Undulating surface with poor grasses and bushes. About 20 m above sea level.

0.0-0.2m: Aggregate of pisolitic and botryoidal iron oxide concretions. Uneven and sharp boundary to;

0.2-0.7m: Hard laterite.

6-iii) 10 km SE of Suong along National Road No. 22

Ground surface: Slightly undulating to flat paddy field with few standing trees. About 18 m above sea level.

0.0-0.7m: Very heavily weathered fine sand with common pink quartz grains and perfectly decomposed feldspars.

0.7-0.9m: Aggregate of pisolitic and botryoidal iron oxide concretions.

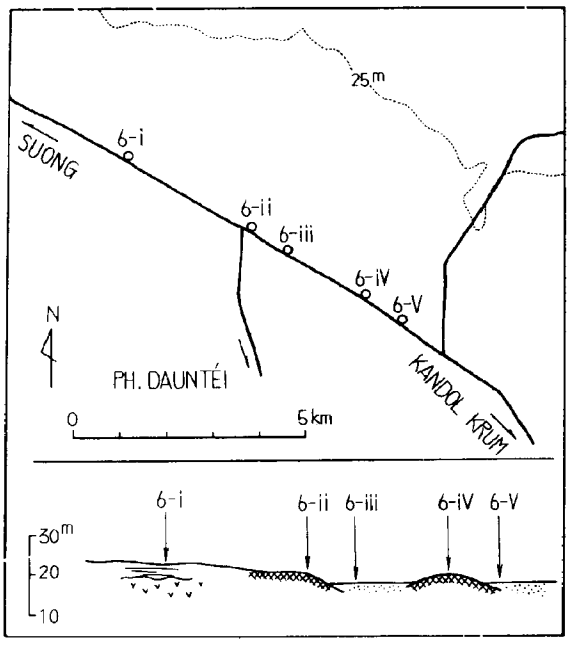


Fig. 7 Geological mode of Kandol Chrum area

6-iv) 12 km SE of Suong along National Road No. 22

Ground surface: Undulating surface with hard lateritic cover. About 20 m above sea level.

6-v) 13 km SE of Suong along National Road No. 22

Ground surface: Slightly undulating to flat paddy field with few standing trees. About 18 m above sea level.

Heavily weathered sands carrying numerous pisolitic and botryoidal iron oxide concretions cover the ground surface.

7. Sandan area

Geological mode of this area is as shown in Fig. 8.

7-i) River floor of the Mekong at Sandan

Mesozoic sandstone. Bedding plane is of N-S, 25°E.

7-ii) Left bank of the Mekong at Sandan

Ground surface: Lower flood plain. Surface is about 5 m above the water level of the Mekong (May 28).

0.0-0.5m : Weakly stratified medium sand; loose.

7-iii) Left bank of the Mekong at Sandan

Ground surface: Higher flood plain. Surface is about 9.5 m above the water level of the Mekong (May 28).

0.0-9.0m : Dark gray medium sand with thin silt seams; weakly current bedded.

7-iv) Back swamp on the left bank of the Mekong at Sandan

0.0-1.0m : Dark brown massive loam.

7-v) 3 km NE of Sandan along National Road No. 13

Ground surface : Slightly undulating surface with a gentle inclination toward the Mekong; covered with dwarf trees and grasses. The topographical feature appears to be an old terrace surface, though no alluvium is found.

7-vi) 7 km NE of Sandan along National Road No. 13

Ground surface: Undulating or rolling surface of about 40 m above the water level of the Mekong (May 29); covered by a dry open forest.

0.0-0.5m : Heavily weathered gravel, composed dominantly of rounded quartzitic rocks, with numerous iron oxide concretions and laterite fragments. A few carbonacious concretions are also seen. Two angular fragments of petrified wood (5 cm×5 cm×10 cm), which were found in the weathered gravel bed may suggest the gravels be most probably of Paleogene in age.

0.5-1.5m : Mesozoic sandstone.

7-vii) 9 km NE of Sandan along National Road No. 13

Ground surface: Undulating or rolling open deciduous forest with grasses.

0.0-0.6m : Gray or yellowish gray compact silty sand with many pink quartz grains. Silty material seems to be dominantly kaolinic. Uneven and very sharp boundary to;

0.6-1.0m : Accumulation of pisolitic and botryoidal iron oxide concretions.

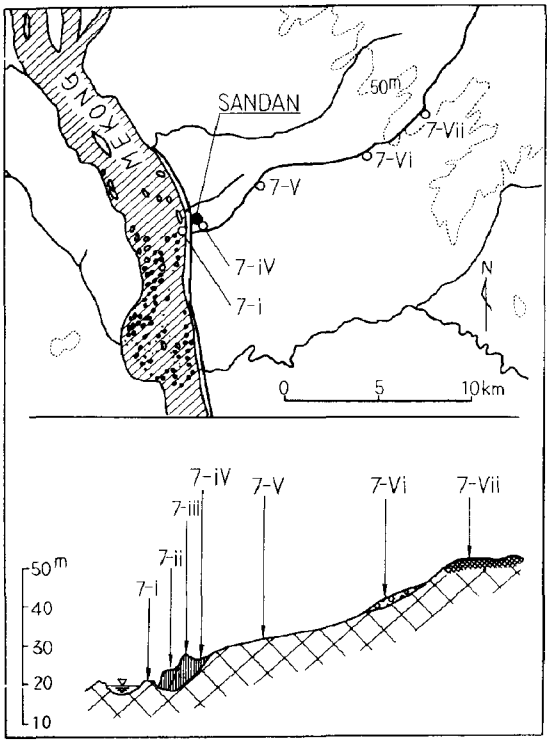


Fig. 8 Geological mode of Sandan area

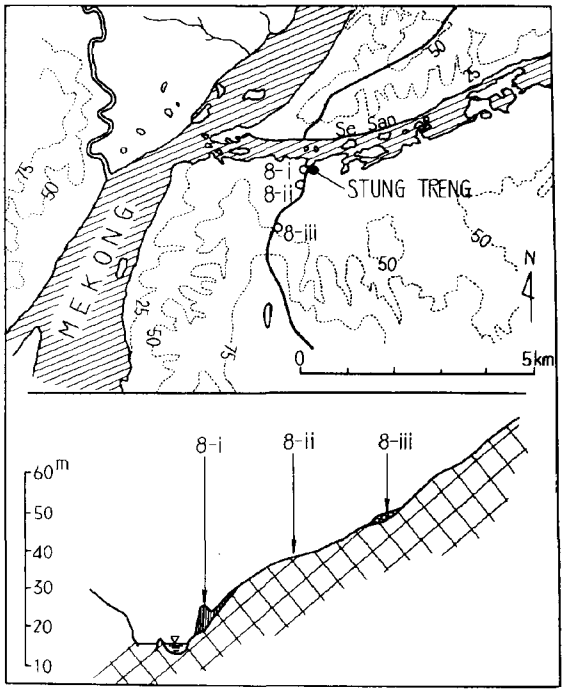


Fig. 9 Geological mode of Stung Treng area

Transforms to a lateritic pan in part. Uneven and sharp boundary to;

1.0-1.7m : Very heavily decomposed Mesozoic sandstone.

This type of succession is common along National Road No. 13 between Sandan and Stung Treng, where a peneplain develops in a large scale.

8. Stung Treng area

Geological mode of this area is as shown in Fig. 9.

8-i) Left bank of the Se San at Stung Treng

Ground surface : Flood plain with a natural levee adjacent to the river and a shallow depression just behind it. Houses are on the natural levee and small swamps in the depressional zone.

0.0-7.0m : Dark gray fine sand with numerous hydromica flakes.

7.0-9.0m : Mesozoic shale and sandstone. Bedding plane is of N 60°E, 80°W. The same kind of Mesozoic rocks exposes on the river bed extensively, forming many small islets.

8-ii) 300 m S of Stung Treng

Ground surface : Slightly undulating, very gently inclined toward the Se San and covered with dwarf trees and grasses.

0.0-1.0m : Heavily weathered sand with Mesozoic sandstone fragments.

Many pink quartz grains and pisolitic and botryoidal iron oxide concretions are scattered.

1.0-1.3m : Mesozoic sandstone.

8-iii) 1.5 km S of Stung Treng along National Road No. 13

Ground surface : Undulating or rolling surface.

0.0-1.0m : Gravels composed of rounded and subrounded pebbles of vein quartz, Paleozoic shale, quartzite, with few fragments of petrifide wood.

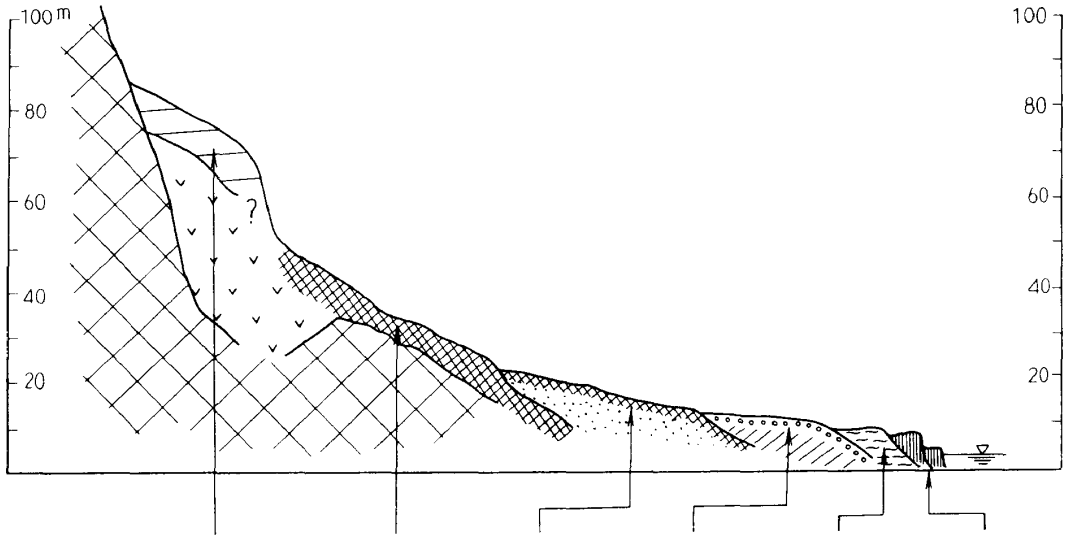
1.0-2.0m : Mesozoic sandstone.

III Discussion

1. Schematic cross section

With the data shown in the previous chapter, a provisional, if not a definitive, schematic cross section can safely be drawn as in Fig. 10.

The Flood Plain is divided into two levels, the lower Flood Plain and the higher one. The former is dominantly sandy and has a depositional surface of 4 m



Formation	Basalt plateau	Thick Laterites Formation	Thin Laterite Formation	Pisolite Formation	Loam Formation	Flood Plain
Sediments	no alluvium	no alluvium(?)	dominantly sandy	dominantly clayey	loamy	dominatly sandy
Weathering feature	red soil	thick hard laterite	heavily weathered alluvium capped by thin laterite	weathered alluvium with pisolitic concretion	alluvium with concent-ration	fresh alluvium with concent-ration

Fig. 10 Schematic cross section of the Quaternary geological bodies in Cambodia

above the river water level (end of May), whereas the latter is 7 to 10 m above the river water level and consists of alternate layers of sand, loam and silt. These formations are confined along the present channel of the Mekong and its tributaries. The outcrops at Locs. 1-viii, 3-iv, 4-iv and v, 7-ii and iii, and 8-i belong to these Flood Plains.

The Loam Formation is composed of a dark brown loam, less than 5 m thick. No distinct weathering features could be seen other than the loose iron oxide concentrations (2 to 4 mm diameter) which are contained in this formation. The flat, depositional surface of the Loam Formation is about 9 to 11 m above the water level of the river (end of May), and develops only along the present and abandoned river courses as in Locs. 1-vii, 2-iii, 3-iii and 4-vii.

The Pisolite Formation is characterized by pisolitic concretions of iron oxide which are scattered in the uppermost horizon of this formation. The concretions are hard, well rounded, of concentric zonal structure and 0.3 to 1.0 cm in diameter. The sediments themselves are dominantly clayey and show a yellowish gray color with brown mottlings in the upper parts due to subaerial weathering and are more or less bluish gray in the lower parts. The thickness is approximately 4 m. The depositional surface, which is slightly undulating and covered mostly with paddies, is 10 to 14 m above the water level of the river. The extension of this formation seems also to have some parallelism with recent river courses. The lower part of the outcrops at Locs. 2-i and 4-vii belong to this formation.

The Thin Laterite Formation is marked by a thin lateritic layer which caps the sediments, and underlies heavily weathered, sandy deposits. The capping, thin lateritic layer is in most cases, composed of loose laterite, 5 to 15 cm in thickness, containing a fair amount of quartz grains (ϕ 0.5-2.0 mm). This laterite is sometimes transformed into an aggregate of pisolitic and botryoidal concretions of iron oxide. In the underlying heavily weathered deposits, no visible weatherable primary minerals can be recognized and a distinctly reticulated, mottled matrix, of bluish gray through yellowish gray to reddish brown hues, is characteristic. The deposits were 5 m minimum thickness, but the real thickness was not measured during the field observation. The depositional surface is slightly undulating and often covered by thorny bushes with patches of paddy, which gives a somewhat savannah like scenery. This formation is seemingly not related to the present setting of the river. Outcrops at Locs. 1-i, 1-iii, 3-i, and 5-iii represent this formation.

The Thick Laterites are distinguished by their greater thickness, hardness and more highly crystalized features than are the Thin Laterite. They vary greatly, however, in their characters according to their geological position. This may reflect the different geneses of these lateritic formations. For instance, the vesicu-

larly textured laterites at Locs. 1-iv and 4-i seem to be a kind of residual ferruginous crust developed on some basic volcanic rocks, whereas the pellety laterites at Locs. 5-ii and 6-ii may be laterized Quaternary alluvia, which are older than the Thin Laterite Formation. The vesiculately textured bauxitic laterite such as at Loc. 7-vii, seems to be closely connected with the peneplain through the Mesozoic Korat series.

The topographical distribution of the Thick Laterites also varies greatly. For instance, at Locs. 6-ii and 6-iv, they gradually submerge beneath the Thin Laterite Formation, whereas the ferruginous crust, at Loc. 1-iv, hangs on the edge of the basement rocks, about 10 m above the Thin Laterite Formation. Those on the Peneplain at Kratie Province are as high as 40 m from the Thin Laterite surface.

As mentioned above, the character of the Thick Laterites Formation are so complicated that it is still premature to determine whether they should be classified into one stratigraphical group or not. It can probably be asserted, however, that the Thick Laterites Formation is older than the Thin Laterite. This reporter is of the opinion that the genesis of the Thick Laterites is more or less closely connected with the peneplanation of the older rocks, which took place just before the deposition of the Thin Laterite Formation.

The undulating ground surface of the Basalt plateau is covered by red soils which are mostly exploited as rubber plantations. The red soils are obviously residual weathering products of the underlying basalt as appear in Loc. 5-i. Unfortunately, the outcrops which directly indicate the stratigraphical relationships between the red soils and the Thick Laterites could not be observed during the trip.

2. Correlation and age

Although definite correlations of two geological bodies can not be made without reference to paleontological evidence, the present data, which provides stratigraphical succession based on the characteristic weathering features of each formation, seems to suffice for establishing provisional correlations between the Cambodian Quaternary deposits and those in Thailand.

The Flood Plains in Cambodia can easily be correlated with those of Thailand based on their fresh sandy facies and the strictly confined configuration along the present river channels.

The Loam Formation in Cambodia, which consists of a dark brown massive loam, is quite similar to the Formation I in Thailand in its lithofacies.

The Pisolite Formation in Cambodia is characterized by pisolitic concretions of iron oxide which are scattered in some 100 cm of the uppermost part of this clayey formation. The same kind of pisolitic concretions are also typically found

in the top part of the Terrace II Formation in Thailand. Based on this fact, it seems most probable to correlate the Pisolite Formation with the Terrace II Formation.

The Thin Laterite Formation in Cambodia furnishes a combination of a capping, thin lateritic layer and underlying heavily weathered sandy deposits, as a good stratigraphical indicator. The Terrace III Formation in Thailand is also consistently associated with a similar combination. This fact implies that the Thin Laterite Formation in Cambodia will correspond to the Terrace III Formation in Thailand.

The Thick Laterites in Cambodia have a wide range of occurrences and of morphological characteristics as mentioned in the previous chapter. It is difficult to determine whether these constitute a distinct stratigraphical horizon or not. But common features are found in the variety of the Laterites, and the distinction from the Thin Laterite Formation is well observed based on their greater thickness, hardness and stratigarphically older position. The same kind of criteria also apply to the Thick Laterites in Thailand. Thus, it may be conjectured that the Thick Laterites in both teritories are corresponding.

If the above mentioned provisional correlations are correct, the age of each formation may be determined as shown in Table 1, based on the data obtained in Thailand.

Table 1

Cambodia	Thailand	Age
Flood Plain	Flood Plain	Holocene
Loam Formation	Terrace I Formation	Holocene of Upperpart of Upper Plaistocene
Pisolite Formation	Terrace II Formation	Upper Pleistocene
Thin Laterite Formation	Terrace III Formation	Middle Pleistocene
Thick Laterites Formation	Peneplain (Thick Laterites Form.)	Lower Pleistocene ?

3. Depositional Environment

Table 2 is a comparison chart of the Quaternary sediments in Cambodia and Thailand. Lithologically, the respective formation of the two regions are highly correspondent. This fact implies an important suggestion for analysing the paleoenvironment of the Quaternary basins of this region.

The sandy materials of the Flood Plain and the loamy facies of the Loam Formation horizon are widely traceable throughout the entire zonal area along the main river courses, both in the Mekong (Cambodia) and the Mae Nam Chao Phraya

Table 2

Cambodia		Thailand	
Formation	Sediments	Sediments	Formation
Flood Plain	Sandy or loamy	Dominantly sandy	Flood Plain Formation
Loam Formation	Loamy	Loamy	Terrace I Formation
Pisolite Formation	Clayey	Clayey	Terrace II Formation
Thin Laterite Form.	Sandy or loamy	Sandy or silty	Terrace III Formation
Thick Laterites Form.	?	No Alluvium ?	Thick Laterites Form. (Peneplain)

(Thailand) drainages. A large scale uniformity in lithofacies can be recognized in the Pisolite Formation horizon too, where clayey material comprises the bulk of the formations throughout both drainages. As for the Thin Laterite horizon, sandy materials prevail, both in Cambodia and Thailand.

The uniformity and/or the high coincidence in depositional materials between the two regions suggests that a similar type of depositional environment has been taking places in both regions during the given period. In other words, some kind of large scale depositional mechanism, rather than a local one, has existed during a part of the Quaternary period. Considering the point, this reporter imagines that eustatic movement may have been more important than local tectonic movement, at least since middle Pleistocene, in this part of peninsular Asia.

J. Gubler[2)] suggested the invasion of marine environments of Quaternary age due to the presence of alum and salt crystals in the post-tertiary formation in Western Cambodia. The topographical features of this young formation appears to corroborate his suggestion. The available data, however, is too scanty as yet to fully elucidate the significance of this point.

References cited

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2) Gubler, J. "E'tudes G'eologiques au Cambodge Occidental," *Bull. Service Geologique de L' Indochine*, Vol. XXII, Fas. 2, pp. 1-176. Hanoi, 1935.